An Open-Source Tool for Automated Generation of Black-box xUnit Test Code and its Industrial Evaluation

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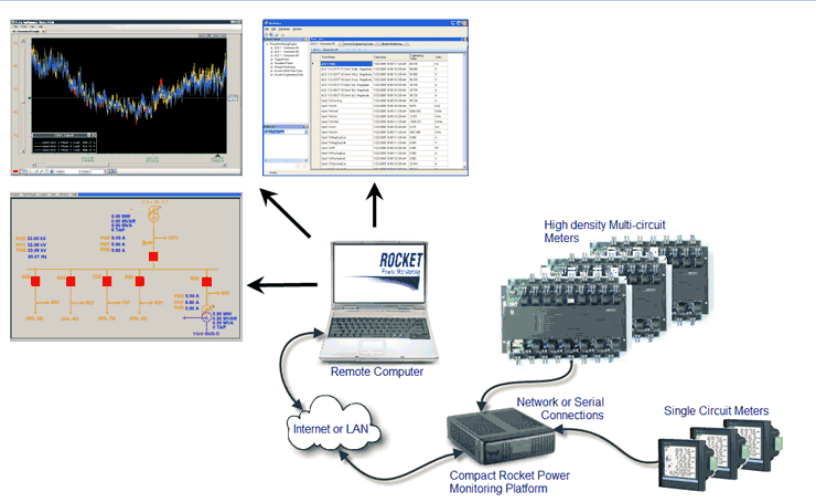
Talk Outline

- Context - Company and the System Under Test
- Units Under Test (Goal: Unit Testing)
- Black-box Unit Testing (BBUT)
- The Automated BBUT Tool
- Evaluation in an Industrial Setting
- Effectiveness in Detecting Defects
- Conclusions
- Q/A

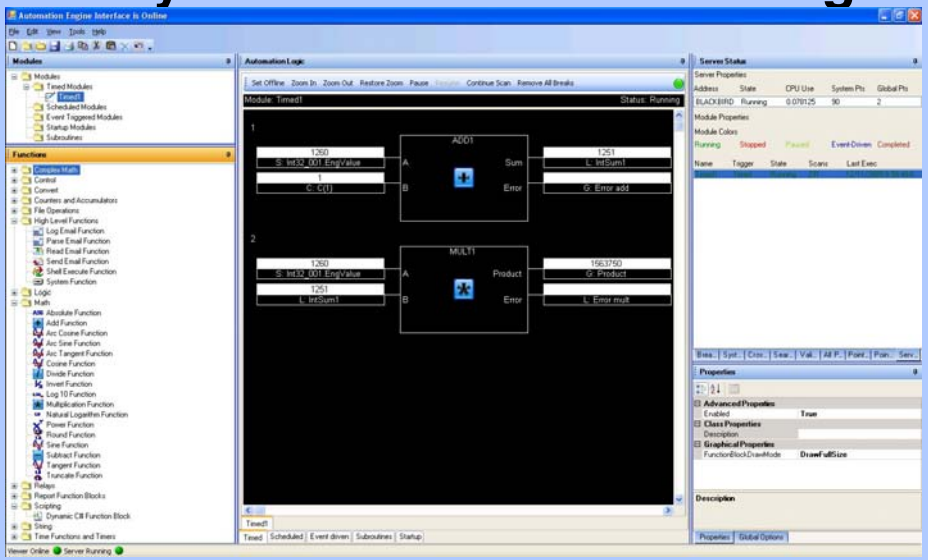
Context - Company and the System Under Test

- A commercial large-scale Supervisory Control and Data Acquisition (SCADA) software system
- Is called *Rocket*
- Has been developed using Microsoft Visual Studio C#
- A total development effort of about 6 man-years.
- Developed using the iterative development process (but not strictly Agile)
- Has now been deployed in several pilot projects and it is well-accepted by the clients.



Context - Company and the System Under Test

- The SUT has only been tested <u>manually</u> during iterations of the development.
- Towards the end of the project, importance of automated testing was felt
- Thus, a collaboration among the authors
- Our goal: to conduct automated and systematic software testing on the entire Rocket platform.
- Meetings between the project stakeholders
- and prioritizing the modules
- we agreed the first system module to be tested is the *Automation Engine.*



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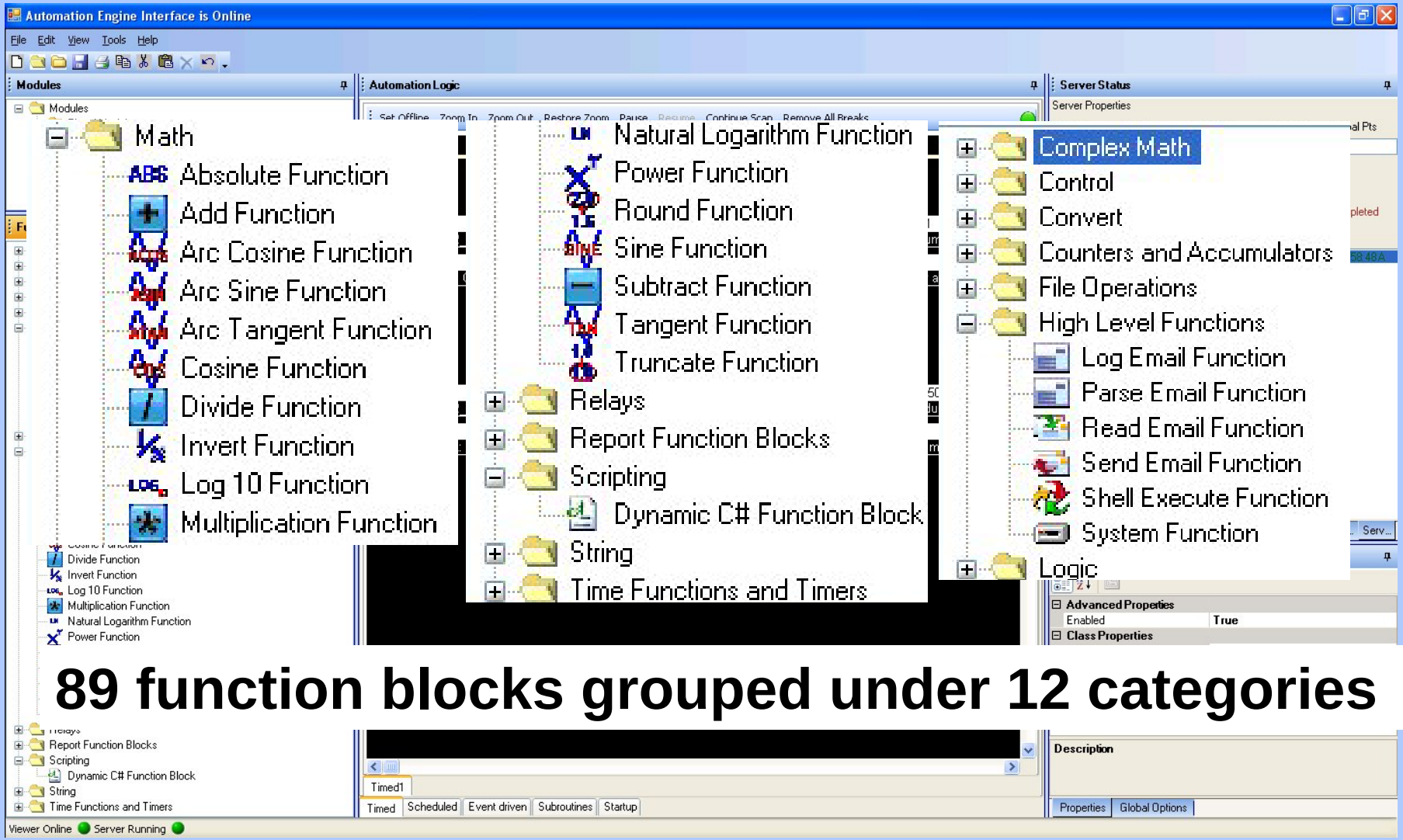
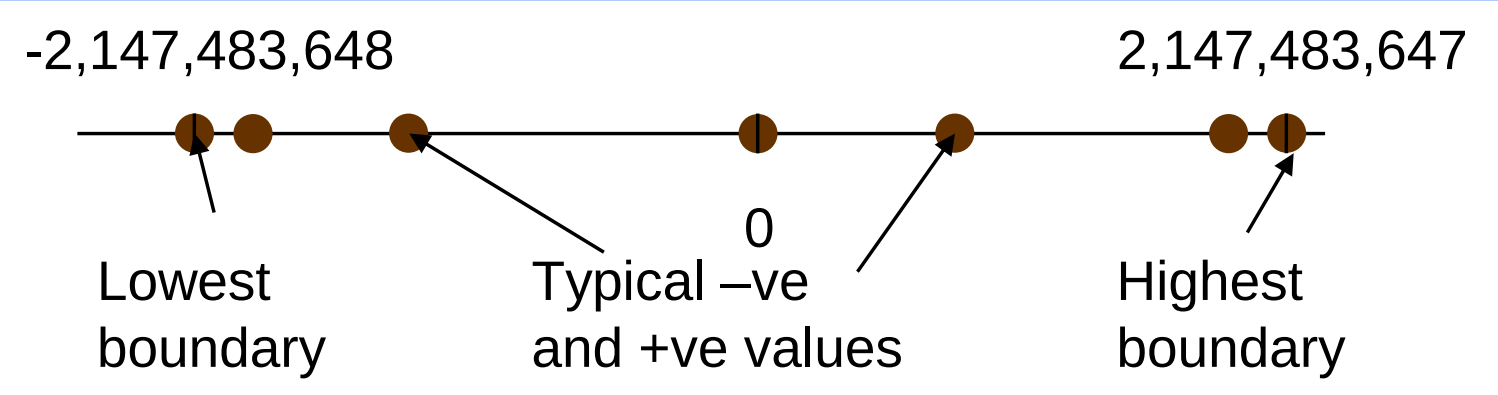
Units Under Test (Goal: Unit Testing)



89 function blocks grouped under 12 categories

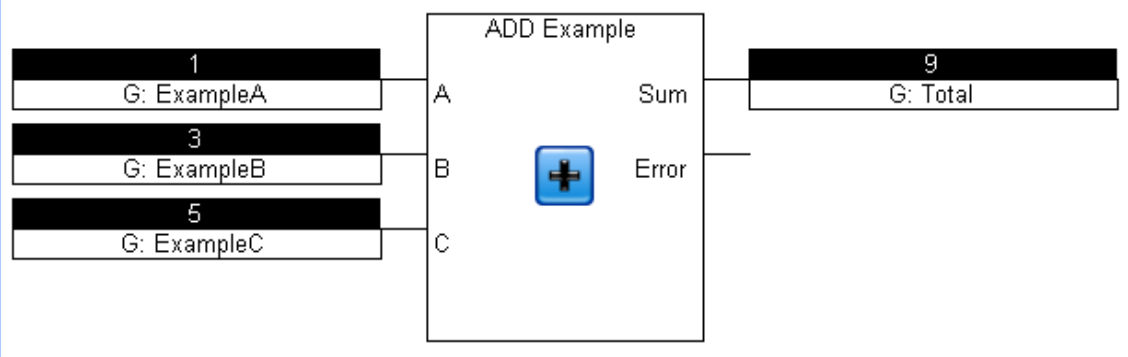
Black-box Unit Testing (BBUT)

Equivalence classes of a 32-bit integer	
1. Nominal positive values	5. Minimum 32-bit integer
2. Nominal negative values	6 .The integer just before the maximum 32-bit integer
3. The value of 0	7. The integer just after the minimum 32-bit integer
4. Maximum 32-bit integer	



Black-box Unit Testing (BBUT): Challenges

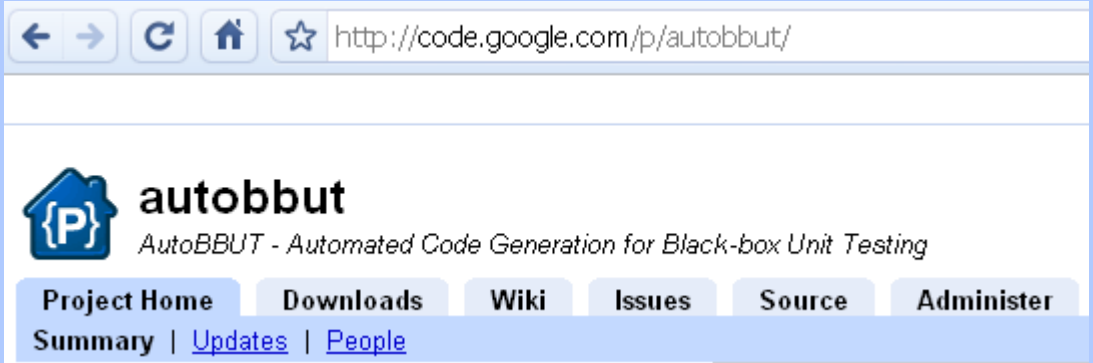
- **The Add function block**



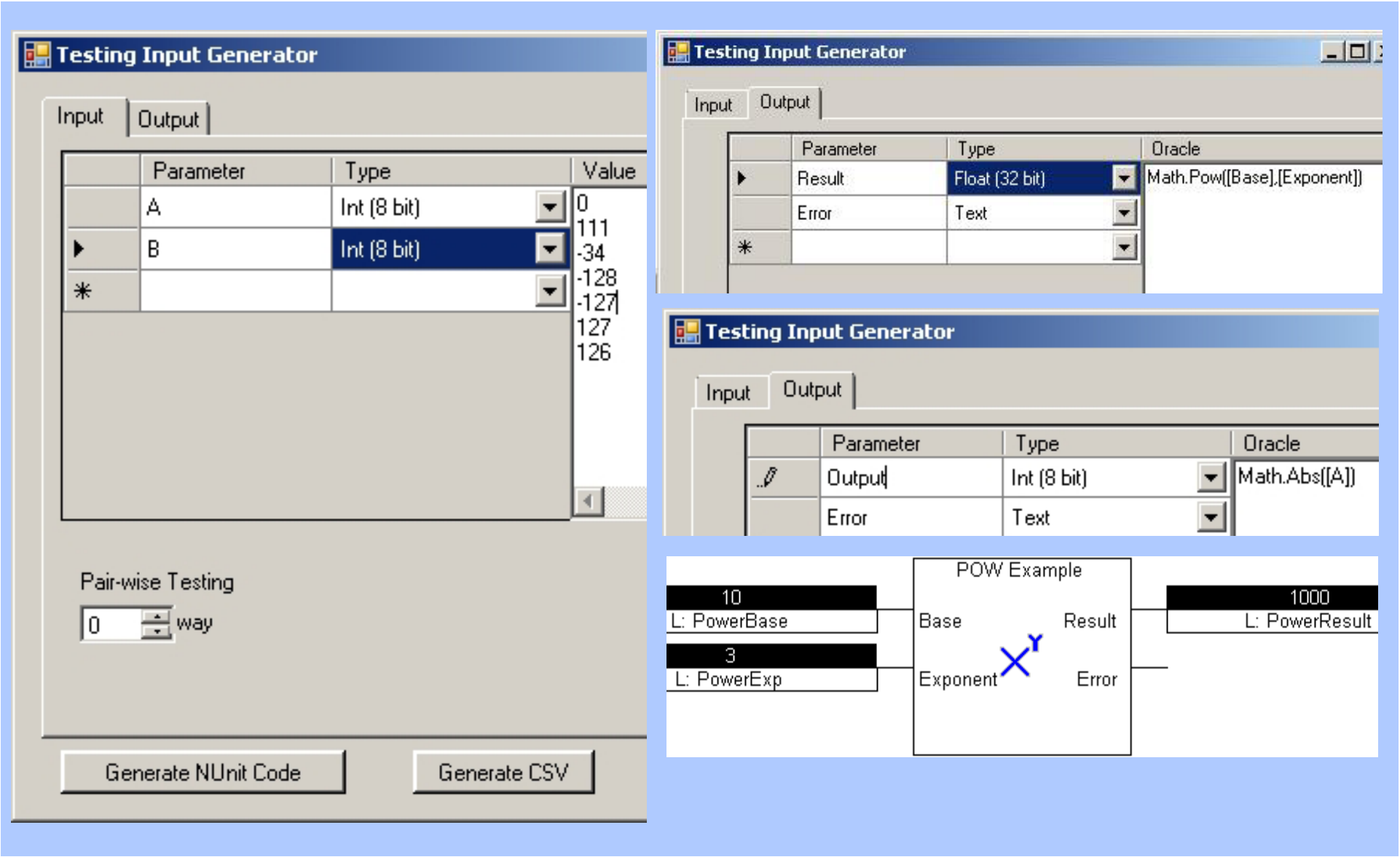
- **If we apply the equivalence classing, we will get 19,683 test cases for only this function block. Bad news ;(**
- **Challenge 1: Coding of test cases (in NUnit): Too much effort**
- **Challenge 2: Coupling of test cases to test input data**
- **Challenge 3: Generation of test oracle**

Black-box Unit Testing (BBUT): Challenges

- **One possible solution → Automated generation of NUnit test code**
- **There are some tools out there:**
  - Microsoft Pex, JML-JUnit, JUB (JUnit test case Builder), TestGen4J, JCrasher, NModel
- **We evaluated those tools for our purpose, but unfortunately, none was suitable (details I the paper)**
- **Decision: to implement our own tool**



AutoBBUT - GUI and Features



AutoBBUT - Example Usage

TestProject.PowerFBTest | Test61642af496604639a6bc3223c659c542()

```
[TestMethod]
public void Test61642af496604639a6bc3223c659c542()
{
    TD.setInputParameter(FunctionBlockName, "Base", "Int (8 bit)", "-128");
    TD.setInputParameter(FunctionBlockName, "Exponent", "Int (8 bit)", "-128");

    RocketParameter resultParam = TD.setOutputParameter(FunctionBlockName, "Result", "Float (32 bit)");
    RocketParameter errorParam = TD.setOutputParameter(FunctionBlockName, "Error", "Text");

    TD.execute(FunctionBlock, FunctionBlockName);

    Assert.AreEqual(float.Parse("1.8929E-270"), float.Parse(TD.getOutputByName(resultParam.PointName)), 0.0001);
    Assert.AreEqual("", TD.getOutputByName(errorParam.PointName));
}

[TestMethod]
public void Test6e134866ed144f3d9c2370bc20cda45f()
{
    TD.setInputParameter(FunctionBlockName, "Base", "Int (8 bit)", "-127");
    TD.setInputParameter(FunctionBlockName, "Exponent", "Int (8 bit)", "-127");

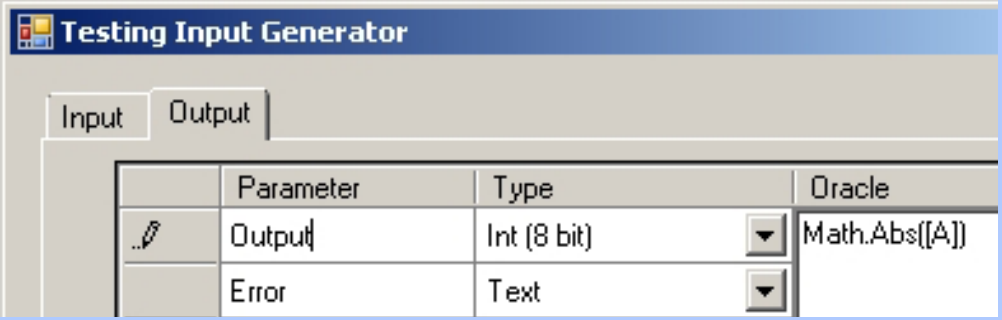
    RocketParameter resultParam = TD.setOutputParameter(FunctionBlockName, "Result", "Float (32 bit)");
    RocketParameter errorParam = TD.setOutputParameter(FunctionBlockName, "Error", "Text");

    TD.execute(FunctionBlock, FunctionBlockName);

    Assert.AreEqual(float.Parse("-6.5604E-268"), float.Parse(TD.getOutputByName(resultParam.PointName)), 0.0001);
    Assert.AreEqual("", TD.getOutputByName(errorParam.PointName));
}
```

AutoBBUT – Technologies (Libraries) used

- **To generate all the n-way test cases, we used a recently-introduced Test API from Microsoft, called `Microsoft.Test.VariationGeneration`.**



- **For the development of automated test oracle generation, we used a utility available in the .NET framework class library, called `System.CodeDom.Compiler`.**
- **CodeDOM: Code Document Object Model**

AutoBBUT - Development Details

- **Developed in C# .Net platform. Consists of 875 LOC.**

InputGenerator.TestInputGenerator | generateTestSuiteCode()

```
// loop over all pairwise test cases
foreach (Variation v in combinatoryModel.GenerateVariations(pairwise_way, 1234))
{
    inputList = new Dictionary<string, RocketParameter>();
    Guid guid = Guid.NewGuid();
    // remove -'s from the random string
    string guidstring = Regex.Replace(guid.ToString(), "-", "");
    // start generating the test method one by one
    testSuiteCode += "[TestMethod]" + Environment.NewLine;
    // test method signature
    testSuiteCode += "public void Test" + guidstring + "()" +
        Environment.NewLine + "{" + Environment.NewLine;

    // feeding the input parameters in to the test code
    foreach (Parameter param in combinatoryModel.Parameters)
    {
        RocketParameter input = new RocketParameter();
        testSuiteCode += "TD.setInputParameter(FunctionBlockName,\"" + input.Name + "\", \"" +
            input.Type + "\", \"" + input.Value + "\" );" + Environment.NewLine;
        inputList.Add(input.Name, input);
    }
    testSuiteCode += Environment.NewLine;

    // feeding the output parameters in to the test code
    foreach (DataGridViewRow outputRow in outputGridView.Rows)
```

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Evaluation in an Industrial Setting

- Only 57 function blocks of 89 function blocks were final in terms of their requirements at this time
- We generated 1,962 NUnit test cases for automated black-box unit testing of 58 function blocks
- The total size of the NUnit test suite is currently 15,906 test LOC.
- Since test case code is automatically generated, each test case method is 8±2 LOC

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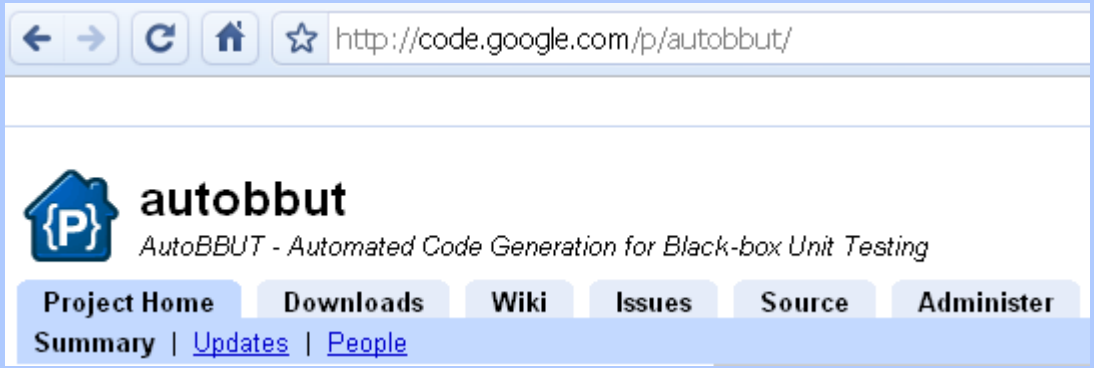
    Assert.AreEqual("", TD.getOutputByName(errorParam.PointName));
}
```

Conclusions

- **An email from the MRCSI's CEO:**
  - *"Many thanks for your efforts. I reviewed your [defect] report. It looks complete and clear. I and am very pleased with the results. We will include all identified bugs to the list and will try to address them."*



- **Open source**
- **A lot of effort has been spent to have a clean design for it which makes it easily extensible and adaptable to other platforms (e.g., JUnit) and SUTs by other testers.**

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